

Electrodiagnostic effect of Armeo® Robotic Therapy versus Conventional Therapy in Erb's Palsy Children

Armeo® Robotic Therapy for Erb's Palsy Children

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Abstract

Aim: This study aimed to examine the efficacy of Armeo robotic therapy versus conventional therapy for upper limb function in children with Erb's palsy.

Material and Methods: Thirty children with Erb's palsy, aged 3 to 5 years, were selected for this randomized controlled study and randomly assigned into two equal groups. The control group (A) received conventional therapy and the study group (B) received Armeo robotic therapy. Intervention for both groups continued 45 minutes, 3 days/week for 12 successive weeks. The range of motion (ROM) of wrist extension using a digital electro-goniometer and the percentages of deltoid and biceps muscle degeneration using Electroneurography (ENoG) were evaluated for both groups before and after the intervention.

Result: A substantial decrease in the percentage of degeneration occurred in the biceps and deltoid in Group (B) compared with that of Group (A) post treatment ($p > 0.001$), and a significant increase occurred in wrist extension ROM in Group (B) compared with that of Group (A) post treatment ($p > 0.001$). The findings obtained clearly endorse the implementation of Armeo® Robotic Therapy as an alternative to care program for children with Erb's palsy.

Discussion: Children with motor dysfunction could be improved using targeted functional training. Variations in repeated movements and enriched environments play an important role in motivating children, thereby enhancing training intensity and effectiveness. The use of robotic machines as a possible rehabilitation strategy for achieving motor recovery may be justified by the beneficial effects on motor learning and therapeutic effects, since robotic training prolongs the duration and increases the training intensity.

Keywords

Erb's Palsy; Armeo®; Robotic therapy; Robot

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Introduction

Brachial plexus birth palsy (BPBP) refers to upper extremity paralysis secondary to traction or compression injury sustained during birth into the brachial plexus. The incidence of BPBP is roughly 0.9 to 2.0 out of 1,000 live births [1, 2]. Erb's palsy is a brachial plexus palsy affecting the upper trunk with nerve root C5-C6 causing loss of balance and arms weakness with internal shoulder twist deformity and hanging arm in limply with wrist and finger flexion typical of the tip of the waiter. Risk factors include dystocia of neck, macrosomia, rough or instrumented delivery, and breech presentation. BPBP varies in intensity and degree of plexus involvement, ranging from acute neuropraxia to the completion of some or all of the brachial plexus root cervical nerve avulsion. BPBP's evolutionary history remains largely unknown due to the lack of research from birth to maturity of affected patients. Historically, 80 to 90 percent of patients were thought to show spontaneous recovery within the first 2 months of life, with normal upper extremity function afterwards [2, 6]. Additional studies have shown a much lower rate of recovery, with just 66 percent of affected children fully recovered, and 10 percent to 30 percent with severe lasting loss [8]. Patients with chronic neurological disorders are at high risk of permanent neurological dysfunction between the ages of 3 to 6 months [2, 3, 6, 10, 11]. For infants who display limited spontaneous neurological recovery, microsurgical reconstruction with nerve grafting or transfers is indicated. The restoration of antigravity biceps activity by 3 to 6 months of age has historically been used to predict long-term neurological recovery. Michelow et al. reported in a small retrospective series that the use of biceps function alone wrongly predicted recovery in 12.8 % of cases [6]. When elbow flexion and elbow, wrist, thumb, and finger extension were combined into a single test score (the Toronto Test score) at 3 months, the proportion of patients whose recovery was wrongly estimated was reduced to 5.2 percent [6]. Researchers explored immersive video games in virtual reality (VR) with stroke individuals and children with CP. The overall results confirm that VR systems enhance upper limb recovery and habilitation. It is proposed that the use of constant massive practice in conjunction with the motivational features integrated in immersive VR games leads to this enhancement [6, 8, 9]. Sensory displays and gaming technologies developed especially for children can provide variety and entertainment value that cannot be accomplished in a typical clinical context [6]. Other authors cite VR as a mean of achieving extended practice times for motor-impaired children, fulfilling one of the key tenants of mass practice [8, 10]. Additionally, exploratory research supporting VR's ability to target specific neural networks can provide potential neuroanatomic treatment strategies for CP rehabilitation [6]. Robotic interfaces allow the shaping of movement patterns with various methods including the actual human-computer interface, haptically rendered obstacles, and global forces such as anti-gravity or damping. Additionally, Fasoli et al. [11] identified a study in which a group of 5–12-year-old children with hemiplegia secondary to CP performed 16, 60-minute practice sessions in a simple virtual environment, with assistance over an 8-week span as required for robotic facilitation. Subjects showed average changes (percentage change from baseline) of 7.49

(13%) in the Upper Extremity Test Performance and 8 (42%) in the Upper Extremity Fugl-Meyer Evaluation ratings, along with anecdotal accounts of increased real-world parental use. A similar pilot study was described by Frascairelli et al [12]. Twelve children with upper limb motor function impairments due to brain lesions completed 18 1-hour sessions to meet specific targets using controlled and unguided movements facilitated by the same robotic device used by Fasoliet al. in the previous study [11], the subjects on average showed an improvement of 3.33 points (9 percent) and an improvement of 6.71 points (12 percent) in the Unilateral Upper Limb Function score in Melbourne evaluation (UEFMA) score. These changes in clinical research were followed by smoothness enhancements of 63 % and trajectory speed enhancements of 40 % assessed during the training [12]. Armeo® spring is a system used for upper limb rehabilitation [13]; it is an exoskeleton that provides gravitational support for the affected upper limb by means of a spring mechanism and magnifies any residual active movement of the hemiparetic arm. As an orthosis with seven degrees of freedom and built-in position sensors, it gives information about specific movement parameters (resistance, strength, range of motion, and coordination), with a possibility to adjust the system sensitivity depending on the patient's condition. In its distal region, the system includes a pressure-sensitive handgrip which allows a graded performance during grasp and release exercises. This system enables participants to practice independent, task-oriented and repetitive movements in a virtual three-dimensional (3D) learning environment, involving central neural pathways related to proprioceptive and visual feedback processing [14,15].

Material and Methods

Subjects

This study included 30 patients with a diagnosis of unilateral obstetric brachial plexus palsy that involves C5–6, as well as positive electroneurography results, suggesting disruption of the innervation in the affected limb for the deltoid and biceps brachii muscles. Children with any other problems than Erb's paralysis were excluded, such as contractures, suffering from fixed limitations in the affected upper limb, musculoskeletal problems, neuromuscular problems or hypersensitivity to latex and adhesive bands.

Materials:

1. **Electroneurography (ENoG)** used to measure percentages of deltoid and biceps brachii muscle degeneration.
2. **Armeo robotic therapy** (Figure 1) is a passive upper limb orthosis, which lightens the weight of the upper limb in 3D space, using an ergonomic and adjustable backrest (antigravity effect), and allows natural movement in the workspace. This makes it easier for users with moderate to severe disabilities to achieve a greater range of motion [12].
3. **Digital electro-goniometer** is used to determine the range of wrist extension.

Procedures:

Study design

A randomized study included thirty children with Erb's palsy selected from the out-patient clinic, Faculty of Physical Therapy, Cairo University (males and females, aged 3 to 5 years).



Figure 1. Armeo robotic therapy

Those meeting the criteria of inclusion were divided into two groups as follows: Group (A) (control) and Group (B) (study). Children in Group (A) received 12 successive weeks of conventional therapy, and group (B) received 12 successive weeks of Armeo robotic therapy.

Ethical consideration

This study was approved by the Cairo University Research Ethics Committee, and written informed consent was obtained from the parents of each subject to participate in this study.

Participant recruitment

All children were randomly assigned equally in two groups using the closed envelopes procedure (30 children each).

A. Evaluation procedure

• Electroneurography (ENoG)

For measuring the percentages of degeneration of the deltoid and the biceps brachii muscles, a computerized electromyography device (Neuroscreen plus – four channels – version 1.59 produced by TOENNIES, 97204 Hochberg, Germany) was used with surface electrodes. To prepare the patient and measure his temperature, he was asked to lie on the examination table in a supine position, per skin from waist-up and the sites required for stimulation and registration were washed with alcohol-damped medical cotton to minimize skin impedance. He was asked to maintain his head in mid position to prevent manifestation of any primitive reflexes that could alter the distribution of tone in his body. ENoG was first performed on the safe side and then replicated on the affected one. The site of the bipolar stimulator was above the Erb's point and the determination of the best position to generate the compound muscle action potential (CMAP) was manually adjusted. For the deltoid, the active recording electrode was placed in the motor point of the posterior deltoid muscle fibers with the reference recording electrode placed farther distally at a relatively quiet point, and the active electrode was placed in the motor point of the biceps muscle with the reference recording electrode placed farther distally at a relatively quiet point for the biceps muscle. The ground electrode was placed under the clavicle's lateral 1/3. A rectangular pulse was developed, with a time base of 5 ms and a frequency of 1 Hz. The intensity of the current stimulation was increased step by step until the amplitude of the diphasic myogenic CAP had not increased further. To be sure of supramaximal stimulation we added about 10 percent of current. The range of stimulation intensity was 15 to 40

mA. For measuring the peak-to-peak amplitude, the software included with the Neuroscreen plus system was used.

- **Digital electro-goniometer** was used to determine the range of wrist extension.

Interventions

1. Conventional Therapy

The Group (A) received conventional therapy for 45 min/session, 3 times/week, for 12 successive weeks. This program included:

1. Passive stretching exercises for elbow and wrist flexors.
2. Weight-bearing exercises for the upper limbs.
3. Stimulation of the protective reactions of the upper limbs in all directions.
4. Exercises facilitating hand skills, such as reaching, grasping, carrying, releasing, in-hand manipulation, and bilateral hand use.

The children performed these exercises while sitting on a chair, while the therapist sat beside to guide and assist them in performing the exercises correctly.

2. Armeo robotic therapy

The Group (B) received practice in a virtual environment, using Armeo® spring (Hocoma, AG, Switzerland). The Armeo® system is a novel tool that combines robotic assistance and virtual reality to provide a unique way to engage children in the repetitive motions required for motor learning. This exoskeleton device provides an engaging environment to help achieve the repetitive practice that the upper extremities need to improve their function. The Armeo system is highly adjustable, allowing the therapist to customize the device to the needs of each child. Armeo equipment is based on the product "T-WREX" [16]. This product is a passive upper limb orthosis, which lightens the weight of the upper limb in 3D space, using an ergonomic and adjustable backrest (antigravity effect), and allows natural movement in the workspace. This makes it easier for users with moderate to severe disabilities to achieve a greater range of motion [17]. The Armeo has five different degrees of freedom: shoulder flexion/extension, shoulder abduction/adduction, elbow flexion/extension, forearm pronation/supination, and grip strength. The therapist can choose to lock out different motions or work on all motions at the same time, depending on the needs of each child. In addition, adjustments can be made to the amount of gravity assistance provided by the exoskeleton, depending on the strength of the upper extremities. The therapist adjusts the electric lifting column according to the child's height while sitting, and the length of the orthosis for upper arm and forearm to avoid compensatory movement. The 3D workspace is then adjusted with the amount of weight support. After feeding the data from each patient into the device, the therapist selects the appropriate program according to the difficulty level; the computer senses the movement of the joint angle and uses the information to provide visual feedback and track the entire process. Patients practiced the Armeo therapy for 45 min/session, 3 times/week, for 12 successive weeks. This provided the high level of repetition required to facilitate changes in the upper extremities [18, 19]. During each 45-minute session, the patients performed a gamut of exercises customized for each patient, under the supervision of a physiotherapist. This study used the standard game and difficulty settings assigned by the Armeo software. The exercises were chosen in order to provide

an engaging and gradual training with increasing difficulty (very easy, easy, moderate, and difficult). The exercises involved different joints (shoulder, elbow, and wrist), defined movements (flexion-extension, abduction-adduction, and pronation-supination, separated or in combination); the movement was to be performed in a 1D, 2D, or 3D environment, with increasing demand for accuracy and/or speed. The system automatically recorded information about the exercise during each training session (such as difficulty level, work area, and weight support), the score obtained by the subject and the time required for the exercise. The games were cognitively engaging and functionally relevant; they visually guided the patient's performance and provided him/her with feedback. As in common video games, a score lets the patient follow his/her performance and improvement over time. The therapist verbally reinforced positive efforts, furnished suggestions, increased the difficulty gradually, and selected the task [4].

Statistical Analysis

The characteristics of the subjects were compared using the t-test for both groups, for comparison of sex and affected side distribution between groups, the chi-squared test was used. For all variables, the normal data distribution was tested using the Shapiro-Wilk method. To test the homogeneity between groups, Levene's test for homogeneity of variances was carried out. Mixed MANOVA was performed to compare the effects of treatment on the percentage of degeneration of the biceps and deltoid and wrist extension ROM between the group A and B as between-group comparison and between pre and post treatment in each group as within-group comparison. Post-hoc tests were carried out using the Bonferroni correction for subsequent multiple comparisons. The level of significance for all statistical tests was set at $p \leq 0.05$. All statistical analyses were conducted using the statistical package for social studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA).

Table 1. Basic characteristics of the participants

	Group A	Group B	p-value
Age, mean \pm SD, years	3.76 \pm 0.53	3.8 \pm 0.45	0.85
Sex, n (%)			
Girls	10 (66.7%)	9 (60%)	0.7
Boys	5 (33.3%)	6 (40%)	
Affected side, n (%)			
Right	12 (80%)	10 (66.7%)	0.4
Left	3 (20%)	5 (33.3%)	

SD: Standard deviation. P-value: Level of significance. n: number. %: Percentage

Table 2. Mean percentage of degeneration of the biceps and deltoid, and wrist extension ROM pre- and post- treatment in groups A and B

	Pre-treatment			Post-treatment			Pre vs post (group A)	Pre vs post (group B)
	Group A	Group B	p value	Group A	Group B	p value	p value	p value
	mean \pm SD	mean \pm SD		mean \pm SD	mean \pm SD			
Percentage of degeneration of biceps brachii (%)	82.8 \pm 4.07	83.4 \pm 4.68	0.71	54.4 \pm 3.92	30.46 \pm 5.56	0.001	0.001	0.001
Percentage of degeneration of deltoid (%)	75.86 \pm 2.23	75.6 \pm 2.58	0.76	42.66 \pm 3.03	21.6 \pm 4.36	0.001	0.001	0.001
Wrist extension (degrees)	35.4 \pm 1.88	35.66 \pm 1.83	0.69	38.53 \pm 1.84	42.73 \pm 2.4	0.01	0.001	0.001

\bar{x} , mean; SD, standard deviation; p-value, level of significance

Results

Table 1 shows the subject characteristics of both groups. There was no significant difference between both groups regarding age, sex or the affected side ($p > 0.05$).

Effect of treatment on the percentage of degeneration of biceps and deltoid and wrist extension ROM:

Mixed MANOVA revealed that there was a significant interaction of treatment and time ($F = 80.81$, $p = 0.001$). There was a significant main effect of time ($F = 1028.67$, $p = 0.001$). There was a significant main effect of treatment ($F = 113.12$, $p = 0.001$).

Within-group comparison

Both groups showed a significant decrease in the percentage of degeneration of the biceps and deltoid post treatment compared with that pretreatment ($p < 0.001$). Also, both groups showed a significant increase in wrist extension ROM post-treatment compared with that pretreatment ($p < 0.001$) (Table 2).

Between-group comparison

There was no significant difference between groups A and B in all variables pre-treatment ($p > 0.05$). There was a significant decrease in the percentage of degeneration of the biceps and deltoid in Group B compared with that in Group A post treatment ($p > 0.001$); and a significant increase in wrist extension ROM in Group B compared with that in Group A post treatment ($p > 0.001$). (Table 2).

Discussion

The study showed that there was a significant decrease in the percentage of degeneration of the biceps and deltoid, which reveals that this kind of therapy is recommended in these cases. History has shown that the vast majority (95.7%) of obstetric brachial plexus paralysis resolved spontaneously, with 92% of recovery over the first three months [8]. In some patients, contractures and deformities can occur rapidly, regardless of the incidence of spontaneous recovery and the transient quality of the paralysis. One should not expect spontaneous recovery, as, despite the complete return of muscle power, limitation of motion and deformity may persist if therapy is delayed [9]. Long-term residual deficits can include progressive bony deformities, muscle atrophy, joint contractures, potential impaired limb growth, shoulder girdle weakness, and/or "Erb's Engram" (elbow flexion accompanied by shoulder abduction) [10]. The findings of this study indicate that Armeo® Robotic Therapy is significantly more effective in improving the upper limb function in children with Erb's palsy than conventional therapy. New technologies

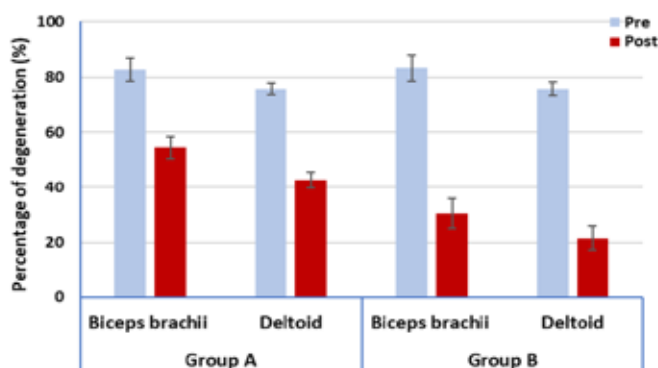


Figure 2. Mean percentage of degeneration of biceps and deltoid pre- and post- treatment in groups A and B.

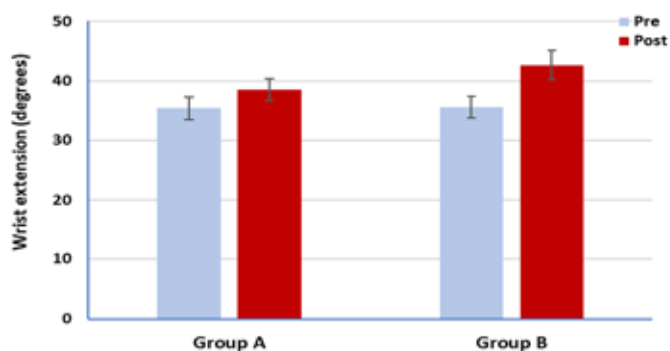


Figure 3. Mean wrist extension ROM pre- and post-treatment in groups A and B

allow and promote active involvement, leading directly to functional changes that are far beyond those obtained with conventional therapy [13]. The main objective of this study on rehabilitating children with Erb's palsy was to restore the basic functional abilities of their arms. Recovery from neural damage usually depends on different factors, such as the nature and extent of rehabilitation. Conventional rehabilitation programs that provide optimum therapeutic results are shorter and less intensive. Children with motor dysfunction could be improved using targeted functional training. Variations in repeated movements and enriched environments play an important role in motivating children, thereby enhancing training intensity and effectiveness. [21]. The use of robotic machines as a possible rehabilitation strategy for achieving motor recovery may be justified by the beneficial impact on motor learning and the therapeutic effect, since robotic training prolongs the duration and increases the training intensity [22]. By using the Armeo system in this study, the therapist was able to manipulate all parameters of exercise, such as duration, intensity and type of feedback, based on treatment goals and individual ability. Therefore children can regularly and with increased enthusiasm perform the necessary tasks. Furthermore, the therapists can track the effects of their gestures and correct them if necessary [23]. During the robotic therapy used in this study, sensorimotor, visual, and auditory input was provided simultaneously with exercise, or at the end of the practice period. The findings of this study are in agreement with those of Glavić et al., who showed that the Armeo spring system is a useful method to

improve the quality of movement of the upper limb. To achieve the best possible outcomes for children with Erb's palsy, it is advisable to supplement conventional therapy with robotic therapy [24]. Improving the consistency of the movement of the study group's upper extremities is associated with vigorous motor activity that can restore and improve neuronal pathways, and increase neuronal plasticity in children with motor deficits triggered by central or peripheral nervous system disorders. In addition to intensive motor training, a goal-oriented and task-specific training program is another requirement for successful rehabilitation. [25].

Conclusion:

We would like to emphasize not only the positive effect of Armeo® robotic therapy, but also the successful motivation of patients at this age. Armeo® Robotic Therapy is significantly more effective than conventional therapy in improving the quality of movement of the upper limb in children with Erb's palsy.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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